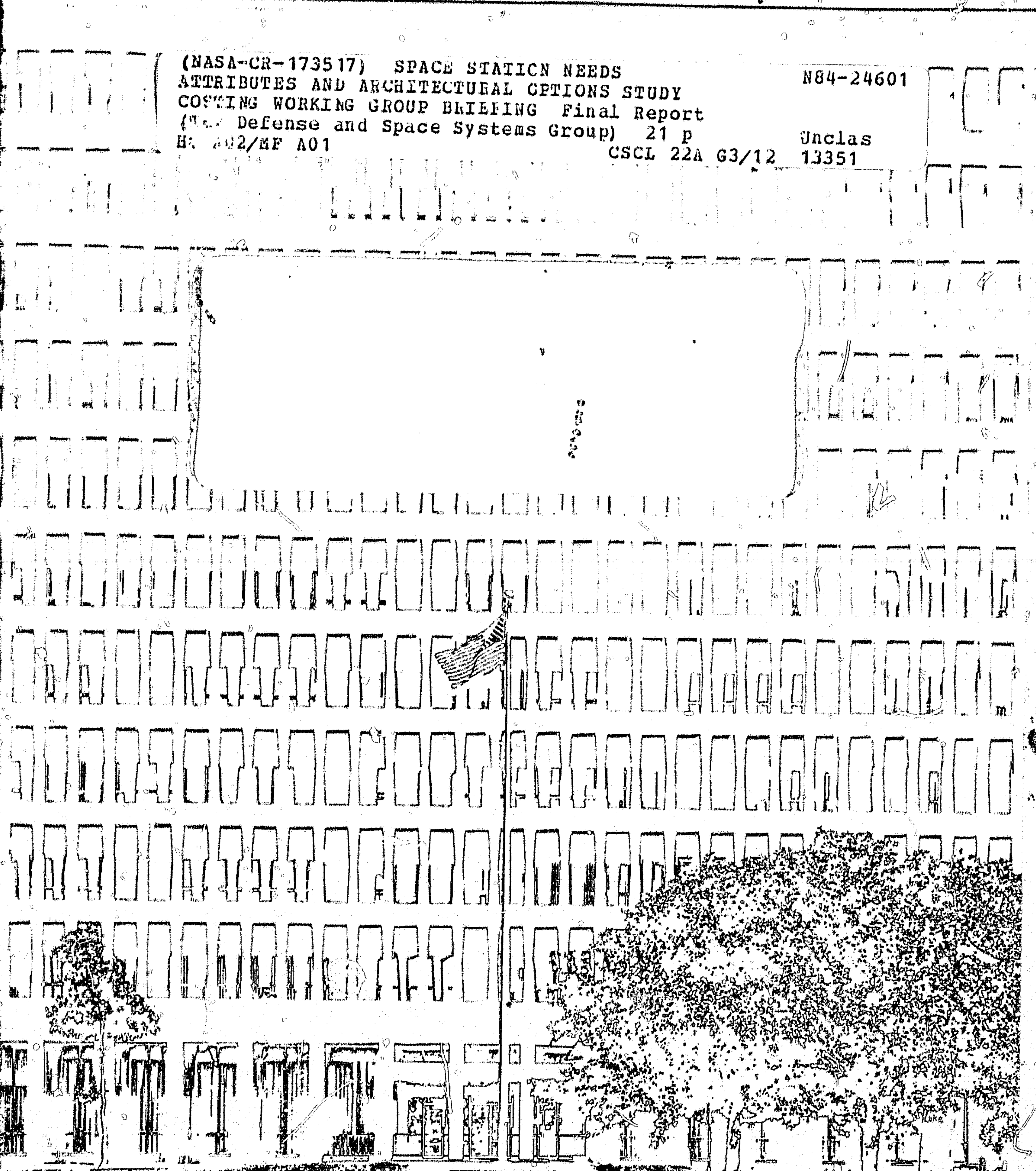
# TRW

NASW-3681

(NASA-CR-173517) SPACE STATION NEEDS ATTRIBUTES AND ARCHITECTURAL OPTIONS STUDY COSTING WORKING GROUP BRIEFING Final Report (TRW Defense and Space Systems Group) 21 p HC A02/MF A01 CSCL 22A G3/12

N84-24601

Unclas 13351



TRW

DEFENSE AND SPACE SYSTEMS GROUP

One Space Park • Redondo Beach, California 90278

MATERIALS PROCESSING IN SPACE
WORKSHOP MINUTES

OCTOBER 27-28, 1982

TRW
ONE SPACE PARK
REDONDO BEACH, CALIFORNIA 90278

# MATERIALS PROCESSING IN SPACE WORKSHOP


## ABSTRACT

A Materials Processing in Space (MPS) workshop was held at TRW in October 1982 as part of the Space Station Needs, Attributes and Architectural Options study that TRW is performing for NASA. Among those present were most of the invidiuals in the United States who understand the promise of MPS and who also are senior technical individuals associated with commercial firms that process materials. They:

1. Endorsed the concept of a United States space station as a desirable national asset.
2. Stated that a commercial MPS research program is mandatory to extend commercialization of space for materials processing.
3. Described in general terms a National Research Laboratory and free flying research facilities that are needed.


## METHOD

To assist in establishing commercial user requirements for a space station system, a Material Processing in Space workshop was held on October 27 and 28, 1982 at TRW, Redondo Beach, California. These requirements will contribute to the product from the TRW Space Station study for NASA (contract number NASW-3681).

At the start, TRW people presented information to the attendees concerning the NASA Space Station Studies, present concept of a space station system, and the status of the NASA MPS program, including initial commercial ventures.

The attendees were divided into three separate working groups. They were asked to address a set of questions that were posed to stimulate thinking about MPS requirements on a space station system. The groups met separately several times in the two days. The attendees met all together each day to summerize the results of the group meetings and for general discussion. During the group and general discussions, TRW personnel acted as facilitators and were expressly instructed to not state their opinions. At the end, a concensus statement was developed and majority opinions were stated and clarified.

Lists of attendees and of involved TRW personnel are Appendices A and B. A list of the suggested initial questions is Appendix C.

## DISCUSSIONS

As each group discussed the questions, they developed summary charts for presentation to the assembled groups. These charts are presented here to assure that the original intent of the group is shown. Comments on the group's discussions are made by the TRW facilitators. Each section is organized in the order of the questions.

### Group 1

Working Group 1 consisted of:

Dr. John Benjamin, International Nickel
Dr. Tom Piwonka, TRW Equipment Group
Colonel Richard Randolph, Microgravity Research Associates
Mr. Nat Kessler, A.E. Staley Manufacturing Company
Mr. William Ryan, Bechman Instruments Inc.
Dr. S. Reed Nixon, MPS Consultant
Mr. T.E. Hanes, TRW Facilitator.

#### Motivation

The group spoke strongly on the subject of commercial research, making three major points.

1. The scenario from applied research to a product takes 15 to 20 years.
2. Basic materials processing science is not a help to development of saleable products, and most research in MPS is now academic.
3. No product can be postulated now. It will take 5 years of research to know if any product is feasible.

A. MOTIVATIONS

1. Push-Pull? MARKET PULL
2. Initial interest
   - Low-g process studies for commercial applications rather than producing material for sale.
3. Indeterminate projection of interest.
4. Current interest - applied materials science/applied process studies.
5. Interest change? Commercialization is a must, product for sale.

Needs

Despite the chart statement, there was a discussion of quantities. With several variables, in addition to composition (for metals), very large experiments are called for. Hundreds of samples will be needed. For metals, 10 grams per sample is minimum, 50 grams if you want to fully characterize the materials.

B. NEEDS

1. How much research? Non-quantifiable, a lot!
2. Lengthy implementation to be addressed!
3. Quick response and sustained effort are essential.

Considerations

The most important consideration that was expressed was that there be an industrial research board or consortium formed to advise on facilities and priorities for their use. It was stated that most small companies, and divisions of large companies can appropriate about $250K for a project, "without going to the Board of Directors."

The space station should be a demonstration of the government's determination of program stability.

C. CONSIDERATIONS

1. What cost level? Under proper conditions, most industries would consider ~ $250K/year. (Conditions: a third-party industrial board or consortium).
2. U.S. space based MPS lab required initially.
3. Complementary activities: Regulatory relief from anti-trust, industrial driven and monitored (see C-1).

D. Space Station Features

It was stated that the space station accommodation of MPS should consist of two parts; a materials laboratory on the station; free flyers for research and for production.

The laboratory should have all equipment needed to characterize the samples metallic, crystal and fluid. The laboratory should have capability to operate processes at partial g levels. It would also be used as a quality control lab for production runs.

Use of man was discussed. Unmanned was stated as the ultimate goal, with robotics technology to be used as soon as feasible. Men, when used, should be qualified experimenters in the discipline.

There was a considerable discussion of electric power requirements for the processing equipment.

D. MSS FEATURES

1. Unmanned ultimate goal - use robotics technology, ASAP
   - Qualified experimenters as required.
2. To accommodate anticipated needs
   - Adequate power e.g., - 5 kW → 50 kW
     Factory vs. station distinction
   - Process

| | |
|---|---|
| High Temperature (quartz) | 25 → 100 kW |
| Metals | 5 → 50 kW |
| Liquid migration | 0.5 → 2 kW |
| Life sciences (e.p.) | 0.1 → 0.5 kW |
| Housekeeping | .1 → 1.0 kW |

<u>Central Station</u>

- Monitor/Control
- Materials Lab:
  - Electron Microscope
  - High Press Liquid Chromography
  - I.R. Spectrometer
  - Warehouse hot/cold
  - Artificial g (0 → 1)
  - High Temperature capability
  - Data telemetry
  - Substrate interaction (capability to enter the process)

<u>Satellites</u>

- Redundant or alternate systems
- Standardized/Modular systems for economy
- In-space test of system

The laboratory should have all equipment needed to characterize the samples metallic, crystal and fluid. The laboratory should have capability to operate processes at partial g levels. It would also be used as a quality control lab for production runs.

Use of man was discussed. Unmanned was stated as the ultimate goal, with robotics technology to be used as soon as feasible. Men, when used, should be qualified experimenters in the discipline.

There was a considerable discussion of electric power requirements for the processing equipment.

D. MSS FEATURES

1. Unmanned ultimate goal - use robotics technology, ASAP
   - Qualified experimenters as required.
2. To accommodate anticipated needs
   - Adequate power e.g., - 5 kW ⟶ 50 kW
     Factory vs. station distinction
   - Process

| | |
|---|---|
| High Temperature (quartz) | 25 ⟶ 100 kW |
| Metals | 5 ⟶ 50 kW |
| Liquid migration | 0.5 ⟶ 2 kW |
| Life sciences (e.p.) | 0.1 ⟶ 0.5 kW |
| Housekeeping | .1 ⟶ 1.0 kW |

Central Station

- Monitor/Control
- Materials Lab:
  - Electron Microscope
  - High Press Liquid Chromography
  - I.R. Spectrometer
  - Warehouse hot/cold
  - Artificial g (0 ⟶ 1)
  - High Temperature capability
  - Data telemetry
  - Substrate interaction (capability to enter the process)

Satellites

- Redundant or alternate systems
- Standardized/Modular systems for economy
- In-space test of system

Recommendations

Group 1 recommendations were as follows:

RECOMMENDATIONS

- Consortium to standardize design of Busy Bee. Design for mass production. B.B. 10 year life, $250K for one company.
- Central station and satellites.
- Reduce lead times.
- Multi-year funding and commitment by NASA needed.
- Reliable schedules.
- Regulatory relief from anti-trust.
- Industry driven and monitored program.

Group 2

Working Group 2 consisted of:

Mr. Jim Graham, Deere and Company
Dr. Robert Roach, Consultant
Dr. Lodewick van den Berg, EG&G
Mr. Donn Walklet, Terra Mar
Mr. Ken Bragg, Parker-Hannifin
Mr. Paul Chase, Beckman Instruments
Mr. Art Stephenson, TRW Facilitator

Motiviation

The group really couldn't agree on whether or not market pull or technology push dominates their motives. There were strong views on either side. They got involved in a long debate about the factors involved. No one was willing to predict the long term and could not see commercialization in space. They saw space more as a tool for research.

**MOTIVATION**

RISKS

REWARDS (?)

PERCEPTION

CAPITAL INTENSITY

Δ

CAPITAL (INTENSIVE) HIGH RISK ← MARKET PULL

LOW CAPITAL LOW RISK → MARKET PUSH

COMPETITION

MARKET CERTAINTY

RISK PROFILE

## Needs

Tended to be a discussion of needs from NASA.

**NEEDS**

1. Sensitive to user requirements, protagonist rather than antagonist.
2. Facilitating legal and technical process.
3. Good data-instrumentation.
4. Dissemination of accurate requirements and specifications.
5. P.R. support - industry communications.
6. Flexibility - shuttle should be more accommodating (user friendly.

## Considerations

The group discussed the progression that they saw in a company's willingness to commit resources.

| COMMITTMENT | | |
|---|---|---|
| 1. | Time and travel. | |
| 2. | Concept definition and evaluation. | |
| | Technical | |
| | Market | |
| 3. | Get-away special - first experiment (low $) | $500,000 |
| 3a. | Buy time | |
| 4. | Joint endeavor/"GTI" option | $10,000,000 |
| 5. | Leasecraft/space station module | |

The group saw NASA's role as shown in the chart. They felt that NASA has not treated industry as a customer.

| NASA's ROLE: |
|---|
| Project Management |
| R&D |
| Selling Congress |
| Selling Industry |

The following chart describes types of users that the group is aware of. Not all users want to go all the way, many being interested only in research.

| TYPES OF USERS | | |
|---|---|---|
| PRODUCERS | SUPPLIERS OF RESEARCH FACILITY | RENTERS OF FACILITIES |
| MAC DAC | GTI | DEERE |
| CONCEPT ——————— | " | CONCEPT |
| PROOF OF CONCEPT ——— | " | PROOF |
| TEST INITIAL ———— | " | LEASE TIME |
| PILOT | RESEARCH FACILITY | |
| PRODUCTION FACILITY | | |
| OPERATION, MARKET PRODUCT | OPERATE BY SELLING TIME | |

Space Station Features

They concentrated on space facility requirements without trying to specify whether or not these requirements would be met with a space station or shuttle or a free-flyer. Three examples of specific research oriented requirements are shown in the charts.

SPACE STATION FEATURES

Basic utilities - Shuttle/free flyer (pallet platform station).
Electrical
Cooling

(1) Furnace (Steel and Cast Iron)

- Multiple samples/50-199/one-half hour per sample
- Power > 1K < 25K
- Programmable (time/temp)
- Exhaust gases
- 4 missions/year
- Vacuum-pressurized 2-3 atmosphere
- Temperature - up to 1500°C (higher for other alloys)
- G's < $10^{-3}$
- Optical microscope (with processing for manned operation)

(2) Surface Treatment of Aluminum and Steel (Applied Research)

- 2 chemical baths
- Temperature 200°C
- Vacuum to 1 atmosphere

- o Samples manipulation/sequential
  100 samples - 10 min/sample
- o 4 missions/year
- o G's < $10^{-3}$

(3) Crystal Growth (Mercuric Iodide) - Radiation Detector

- Furnace 120°C - 5-30 day duration
- Spacelab environment (ambient air)
- Crystal growth observation by man
- Later development production———— eventual requirement for longer duration missions
- Venting due to toxic fumes if sample breaks
- G's < $10^{-3}$

Not necessarily a continuous production operation

- Early stage experimentation

Primarily for studying the process

(4) Foamed Metals - Potential High Value/High Volume/High Production

- Light - high strength/prosthetic

Recommendations

Group 2's recommendations were as shown in the chart. A lot of the discussion centered around mechanisms to reduce industry risk.

RECOMMENDATIONS

- Contract: To protect against commercial risk - (potential insurance implications)
  - guaranteed capability (Gov't committment) damages are defined in advance
  - More than single year commitments
- Mechanism for promoting intermediary commercial functions/new ventures (GTI, Microgravity Research Associates)
  - Promoting & facilitating private initiatives
  - Intermediary functions
- Brokerage Function
  - Balancing user requirements, with NASA's technical capability, with funding reality
- Revitalize NASA MPS Program
- Education & PR Support
  - Dialogue instead of "Talking Down" to industry, user awareness
- Establish S. S. Architecture which is:
  - User oriented
  - Technically & Commercially feasible
- S. S. Program (from the start) must have potential for commercial feasibility
  - Market analysis
  - Incremental growth
  - Creative private financing

Group 3

Working Group 3 consisted of:

Dr. Edmund Young, DuPont Chemical
Dr. Robert Shaw, Robert Shaw Associates
Dr. Waldo Rall, U.S. Steel
Mr. David Waltz, Beckman Instruments
Mr. Joe Underwood, Northrop Corporation
Mr. David Yoel, Utah State University
Dr. John Kropp, TRW Facilitator

Motivation

There was strong group feeling that initial research must identify any commercialization process. There was, further, a feeling that no one knows enough now to forecast any process that will be commercially feasible in space. None of the group, in fact, foresaw any process that would be better performed in space. One analogy was made to Radiation Chemistry, in which several new products evolved but each was eventually adapted to a process using standard technology. If any product improvements are identified from space research, the push will be toward identifying a corresponding ground-based process.

| MOTIVATION |
| --- |
| 1. 90% market pull<br>10% technical push |
| 2. Initial interests are basic understanding of low g effects on process. |
| 3. Cannot project past initial interests. |
| 4. Primary interest: materials science (serve applications) |
| 5. Are primary interest likely to change? Low probability (except for government or defense). |

Needs

There was a group-wide feeling that NASA is not responsive toward industrial research needs. Further, an important consideration was the guaranteed continuance of STS flights and of research opportunities.

NEEDS

1. How much research to understand process? 75-100 experiments (not necessarily 100 flights) Shuttle first, then committ to platform.
2. Should implementation time be reduced? Yes (progress is evident)
3. Is quick response and sustained effort important?
   a. Yes
   b. Assured continuance of Program

Considerations

They concurred that the government should realize that industry will not commit up-front dollars to very high risk programs with both high capital requirements and a low probability of success.

CONSIDERATIONS

1. a. Current estimated value > $100K/kg
   b. $\leq \$10^6$ to government (from an industrial participant)
   c. Incremental funding upon success or risk reduction
2. General purpose space based laboratory makes sense.
3. Complementary activities? Ground based support, improved patent and licensing policies.

## Space Station Features

There were strong group feelings on some subjects.

- The fundamental research should be done on short duration missions where samples are readily retrievable. The concept of a space facility cannot be an alternative to ground-based analysis.
- There is no need for space station before 1990.
- Space station is not conceived to be a test bed but rather a unit in which to conduct commercial processes previously developed.
- Unmanned modules are indicated for most commercial processes indicated.
- There must be quicker turn-around times than at present to maintin industry interest.
- One member of the group felt that the production of detectors in space could be a profitable area.

1. Options and Timing
   a. No specific, identifiable need for space station before 1990.
   b. Need more shuttle time.
      1. More intelligent use of detachable pallets.
      2. More flight time and flexible use scheduling.
      3. Five years to determine specific requirements for space station.
   c. Less than five years to implementation of space station from decision.
2. Cost effectiveness cannot, and need not, be quantitatively justified.
   a. Basic research.
   b. National interest.
      1. Security
      2. Industry
3. Used for commercial production.
   a. Few identified uses at this time.
   b. Limited research use anticipated if shuttle is still available.

Recommendations

Group 3's recommendations were as follows:

RECOMMENDATIONS

1. Do not commit to space station too early.
2. Exploit opportunities of shuttle first.
    a. More and better planning.
    b. Anticipate five year schedule to delineate space station specifics.
3. Plan to implement space station in less than five years from "go" decision.
4. Organize industry/user council for intelligent interim planning.
5. NASA should be more reseptive to external inputs develop a "how you can" approach rather than "why you can't".

CONCLUSIONS

As a result of the small group and total group discussions the following summary statements can be made:

Motivations

- Industry R&D is motivated largely by market pull rather than technology push.
- Initial interest is low-g materials research.
- To go farther, commercial market assurance (saleable product) is a must.

Needs

- 50 to 100 research samples are required to understand a process.
- Must reduce lengthy implementation time (need 1 year to data from go-ahead).
- Need assurance from government that programs supporting the effort will continue.
- Only production requirements projectable now are by McDonnell Douglas/ Johnson and Johnson and by Microgravity Reserach Associates.

Space Station Features

- A general purpose MPS Research LAB can be defined - parameters were offered.
- Man-in-the-loop experiments on a space station will be useful for research.
- Research will be performed on a free-flyer or space platform.
- Production will probably be performed on a free-flyer.

The following statements were endorsed by the majority of attendees.

1. A space station is required to extend and complete industry interests in R&D.
2. An evolutionary approach to space station is desirable - more R&D is needed.
3. Both a national laboratory on the space station and free-flying platforms will be needed.
4. Quantifying commercial production needs is highly speculative at this time. Five years of additional industrial research is needed.
5. Generic MPS research missions can be specified. Commodity needs (power, cooling, experiment numbers) are large and can be projected now.
6. Industry does not believe that NASA understands their needs
   - MPS research program requirements are developed by academic comcumity - not industry
   - Suggest establishing a commercial MPS User Council or Consortium to advise NASA
7. Costs to participate must be reasonable, and project lead times shortened (12-14 months) for significant commercial activity to occur.
8. Industry is reluctant to invest large amount now
   - High risk programs with both high capital requirements and low probability of success are not often supported.
   - More than single year program commitment is needed.
   - More guarantees by government are needed (e.g., guaranteed existence of capability).

Attachment A

ATTENDEES

Dr. John Benjamin (914) 578-5629
General Manager
INCO Mechanical Alloyed Products
Inco-Sterling Forest
P.O. Box 200
Suffern, New York 10901

Dr. Lodewick Van Den Berg
EG&G
130 Robin Hill Road
Goleta, CA 93117

Mr. Ken Bragg
Parker Hannifin Corporation
18321 Jamboree
Irvine, CA 92715

Mr. Paul Chase (714) 773-8156
Beckman Instrument Inc.
2500 Harbor Boulevard
Fullerton, CA 92634

Mr. Jim Graham (309) 752-6955
Senior Research Associate
Deere and Company
John Deer Road
Moline, IL 61265

Mr. Nat Kessler (217) 423-4411
A.E. Staley Manufacturing Company
P.O. Box 151
Decator, IL 52575

Mr. S. Reed Nixon (801) 225-0991
Consultant
1160 South State #240
Orem, Utah 84057

Dr. Thomas Piwonka (216) 383-3296
TRW
23555 Euclid
Cleveland, OH 44117

Colonel Richard L. Randolph (205) 881-6670
President
Microgravity Research Associates
P.O. Box 323443
Coral Gables, FL 33134

Dr. Robert D. Roach
Consultant
4540 Greenbriar Road
Williamsville, NY 14221

Mr. William T. Ryan
Government Affairs Office
Beckman Instruments Inc.
2500 Harbor Boulevard
Fullerton, CA 92634

Dr. Robert F. Shaw (201) 635-0857
Robert Shaw Associates, Inc.
83 Elmwood Avenue
Chatham, NJ 17928

Mr. Joe Underwood (213) 377-4811
Northrup Research & Technology Center
Palos Verdes, CA 90274

Mr. Donn C. Walklet (415) 964-6900
Terra Mar, Inc.
2113 Landings Drive
Mountain View, CA 93043

Mr. Dave Waltz (714) 773-7790
Financial Analyst
Office of the Treasury
2500 Harbor Boulevard
Fullerton, CA 92634

Mr. David Yoel
327 North 200 East
Logan, Utah 84321

Dr. Edmond G. Young (302) 774-5844
Central Research & Development Dept.
E.I. DuPoint de Numours & Co.
Wilmington, DE 19898

Attachment B

TRW ATTENDEES

Dr. Frederick S. Brown, R5/1281
TRW Space & Technology Group
Product Line Manager
One Space Park
Redondo Beach, CA 90278
(213) 535-0160

Mr. Robert Hammel, R4/2136
TRW Energy Development Group
One Space Park
Redondo Beach, CA 90278
(213) 535-0279

Mr. Thomas E. Hanes, R5/1271
TRW Space & Technology Group
Space Station Project
One Space Park
Redondo Beach, CA 90278
(213) 535-2584

Dr. John L. Kropp, 105/2826
TRW Space & Technology Group
One Space Park
Redondo Beach, CA 90278
(213) 535-4723

Mr. Robert E. Sharples, R5/1271
TRW Space & Technology Group
Space Station Project Manager
One Space Park
Redondo Beach, CA 90278
(213) 535-2584

Mr. Arthur G. Stephenson, R5/1271
TRW Space & Technology Group
Space Station Project
One Space Park
Redondo Beach, CA 90278
(213) 535-1425

Mr. Donald M. Waltz, SNTG/1476
TRW Space & Technology Group
One Space Park
Redondo Beach, CA 90278
(213) 536-1509

## Attachment C

SUBJECT A - MOTIVATIONS

- DO YOU GENERALLY PROCEED WITH R&D BASED UPON MARKET PULL OR TECHNOLOGY PUSH?
- ARE YOUR PROJECTED INITIAL INTERESTS PRIMARILY IN A PRODUCT FORM, E.G., DEVICE OR SUBSTANCE PRODUCED IN SPACE; MATERIALS PRODUCED IN SPACE USED IN A PRODUCT PRODUCED ON EARTH, OR IN LOW g PROCESS STUDIES?
- CAN YOU PROJECT HOW FAR YOUR INITIAL INTERESTS MIGHT LEAD YOU?
- WOULD YOU CLASSIFY YOUR CURRENT INTERESTS AS PRIMARILY MATERIALS SCIENCE, MATERIALS APPLICATIONS, OR OTHER?
- ARE YOUR CURRENT INTERESTS LIKELY TO CHANGE TO COMMERCIALIZATION?

SUBJECT B - NEEDS

- HOW MUCH LOW GRAVITY RESEARCH (EXPERIMENT TIME OR SAMPLES) WOULD YOU SPECULATE YOU NEED TO ESTABLISH PROCESS UNDERSTANDING, CONTROL AND UTILITY?
- DO YOU BELIEVE REDUCING THE LENGTHY PROCESS THAT RECENT AND CURRENT EXPERIMENTS TAKE TO IMPLEMENT TO BE AN ESSENTIAL ISSUE WHICH MUST BE ADDRESSED IN THE SPACE STATION STUDY?
- IS A QUICK RESPONSE AND SUSTAINED EFFORT (CAPABILITY) ESSENTIAL TO YOUR TECHNICAL OR OTHER OBJECTIVES?

SUBJECT C - CONSIDERATIONS

- AT WHAT COST LEVEL WOULD YOU CONSIDER PARTICIPATION IN THE MPS PROGRAM?

- WOULD YOU THINK A GENERAL PURPOSE U.S. SPACE BASED MPS LABORATORY WOULD MAKE SENSE?

- WHAT COMPLIMENTARY ACTIVITIES OR INSTITUTIONAL INVOLVEMENTS DO YOU BELIEVE WOULD BE REQUIRED FOR USING A SPACE STATION TO PERFORM MPS?

-

SUBJECT D - SPACE STATION FEATURES

- WHAT ARCHITECTURAL FEATURES DESCRIBED IN THE OVERVIEW BRIEFING APPEAR MOST APPROPRIATE OR ADAPTABLE TO YOUR INTERESTS?

- WHAT OPERATIONAL FEATURES APPEAR MOST APPROPRIATE?

- WHAT SPACE SYSTEMS CAPABILITY, EITHER MANNED OR UNMANNED, BUILD-UP (DEVELOPMENT) DO YOU THINK NECESSARY?